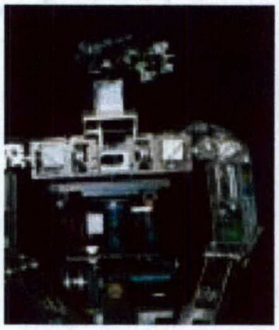
# Development of the "mirror system": a computational model

Giorgio Metta (1,2), Lorenzo Natale (1), Satyajit Rao (1), Giulio Sandini (1)

(1) LIRA-Lab, DIST, University of Genova, Italy
(2) MIT, AI-Lab, Cambridge, MA, USA



**The project**

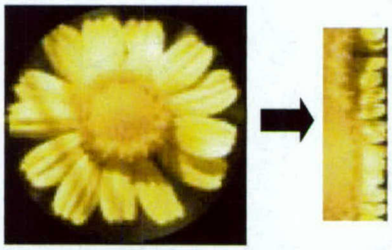
We are studying the development of the mirror system from a computational perspective with the ultimate goal of realizing a physical implementation. We use an anthropomorphic robot as development platform. The body of the robot provides the physical interaction between the computational structure and the environment.

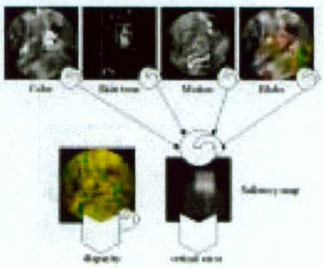
**Motivation**

Single neuron recording and microstimulation in the monkey have shown that the premotor cortex contains visually responsive neurons [1-2]. These neurons are thought to encode visual characteristics of objects in motor terms. For example, area F5 contains neurons that respond both when the monkey grasps an object and when it only fixates the object (canonical neurons). Irrespective of the intention of actually performing that particular motor act, the brain keeps a representation of the potential motor acts. F5 is quite a remarkable area. It contains also another class of visuomotor responsive cells called "mirror neurons". They too fire when manipulating an object but also when one is watching somebody else performing the same sort of manipulation. Pretending the gesture does not make the neurons to fire: that is, the action has to be goal-directed. There is evidence of a similar system in human. Rizzolatti et al. [3] proposed an intriguing hypothesis linking the mirror system to language.

**Approach**

Grossly simplifying, F5 can be imagined as the result of a two-stage process. During the first stage a representation, analogue to the canonical neurons, is acquired. This procedure indeed only requires an error signal about the success or failure of the manipulative action, e.g. if grasping of a cup is successful then associate its description to the visual and motor description of the action of grasping the cup. The second stage accounts to associating, in a single mirror cell, an observed action to the one's internal representation acquired at stage one. For example, watching the action of grasping the cup can be put in correspondence with the canonical representation of it. The goal becomes the reinforcing signal asserting whether both action and object were the same in the two cases.





**What is already implemented… [4-5]**

**Visual competencies:**

- Logpolar vision. The space variant sampling allows maintaining a large field of view and at the same time processing a limited number of pixels.
- Color processing: blob detector, color based segmentation, skin color detection.
- Motion detection: optic flow.
- Binocular disparity.
- Arm localization using proprioception.

**Motor behaviors:**

- Pursuit and saccadic behaviors.
- VOR-like eye movements: employing inertial information.
- Eye/head coordination.
- Reaching and poking/pushing of objects.

**Work in progress…**

- Grasping, control of a robot hand, manipulation
- Machine learning techniques
- Action representation for learning, primitives?

**References**

[1] A. Murata, L. Fadiga, L. Fogassi, V. Gallese, V. Raos, and G. Rizzolatti, "Object representation in the ventral premotor cortex (area F5) of the monkey," *Journal of Neurophysiology*, pp. 2226-2230, 1997.

[2] L. Fadiga, L. Fogassi, V. Gallese, and G. Rizzolatti, "Visuomotor neurons: ambiguity of the discharge of 'motor' perception?," *Internation Journal of Psychophysiology*, vol. 35, pp. 165-177, 2000.

[3] G. Rizzolatti and M. A. Arbib, "Language within our grasp," *Trends in Neurosciences*, vol. 21, pp. 188-194, 1998.

[4] G. Metta, G. Sandini, and G. Konczak, "A Developmental Approach to Sensori-motor Coordination in Artificial Systems," presented at IEEE Conference on System, Man and Cybernetics, San Diego (USA), 1998.

[5] G. Metta and P. Fitzpatrick. *Better Vision through Manipulation*. In *Second Intl. Workshop on Epigenetic Robotics: Modeling Cognitive Development in Robotic Systems.* August 10-11, 2002 Edinburgh, Scotland (forthcoming).

**Acknowledgments**

The research has been funded by the Italian Space Agency (ASI), and by the European Union grants MIRROR (IST-2000-28159) and CVS (IST-2000-29375).
Giorgio Metta is postdoctoral associate at MIT with a grant from DARPA as part of "Natural tasking of robots based on human interaction cues" DABT 63-00-C-10102.
The work on COG has been developed together with Paul Fitzpatrick at MIT, AI-Lab.